Overview of Integrated Multi-Satellite Retrievals for GPM (IMERG) and Data Products

George J. Huffman(1)

[and David T. Bolvin(1,2), Dan Braithwaite(3), Kuolin Hsu(3), Robert Joyce(4,5), Christopher Kidd(1,6), Eric Nelkin(1,2), Soroosh Sorooshian(3), Pingping Xie(5), Jackson Tan(1,7)]

(1) NASA/GSFC Earth Sciences Division – Atmospheres
(2) Science Systems and Applications, Inc.
(3) Univ. of California Irvine
(4) Innovim
(5) NOAA/NWS Climate Prediction Center
(6) Univ. of Maryland / ESSIC
(7) Univ. Space Res. Assoc.

george.j.huffman@nasa.gov

1. Introduction – The Constellation

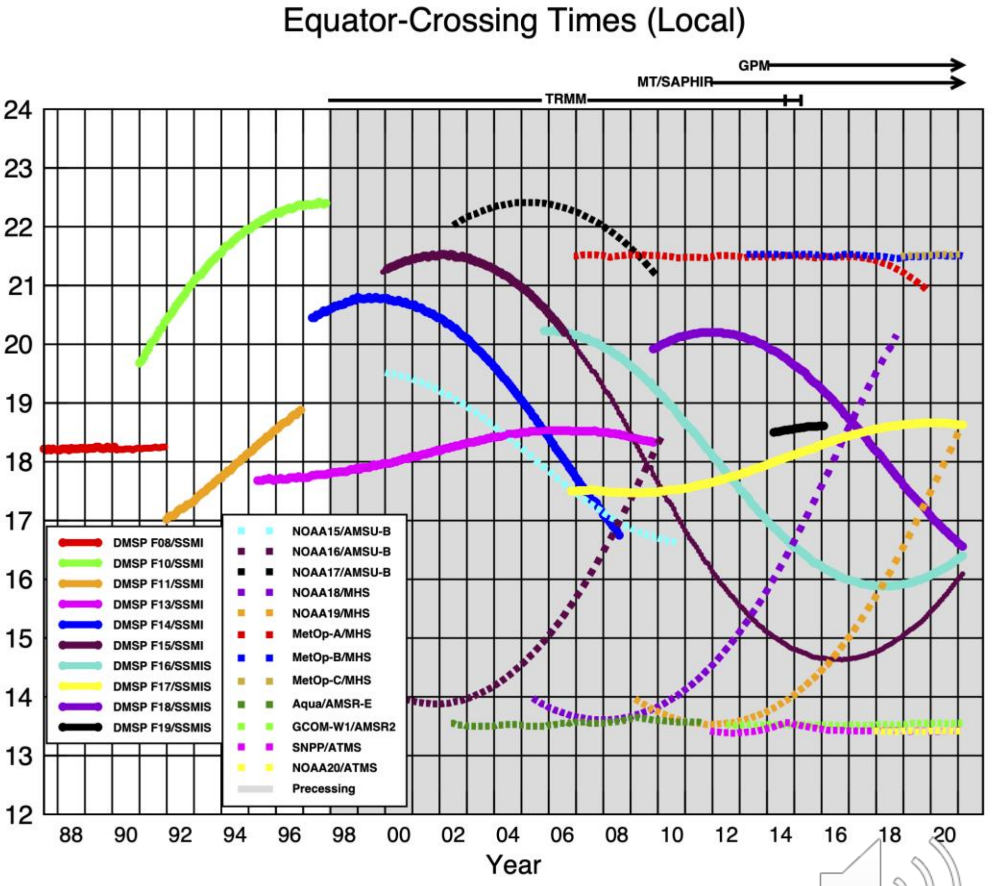
Presently 3-hourly observations >90% of the time, globally

The current GPM constellation includes:

- 5 polar-orbit passive microwave imagers
- 6 polar-orbit passive microwave sounders
- input precip estimates
  - GPROF (LEO PMW) + PRPS (SAPHIR)
  - PERSIANN-CCS (GEO IR)
  - CORRA (combined PMW-Ku radar)
  - GPCP SG (monthly satellite-gauge)

The constellation is evolving

- launch manifests are assured for sounders, sparse for imagers
- how will we cope with short-lived smallsats?



Ascending passes (F08 descending); satellites depicted above graph precess throu[...] the day.
Image by Eric Nelkin (SSAI), 21 April 2021, NASA/Goddard Space Flight Center, Greenb[...]lt, MD.

2. From Data to Estimates – Single-satellite estimates

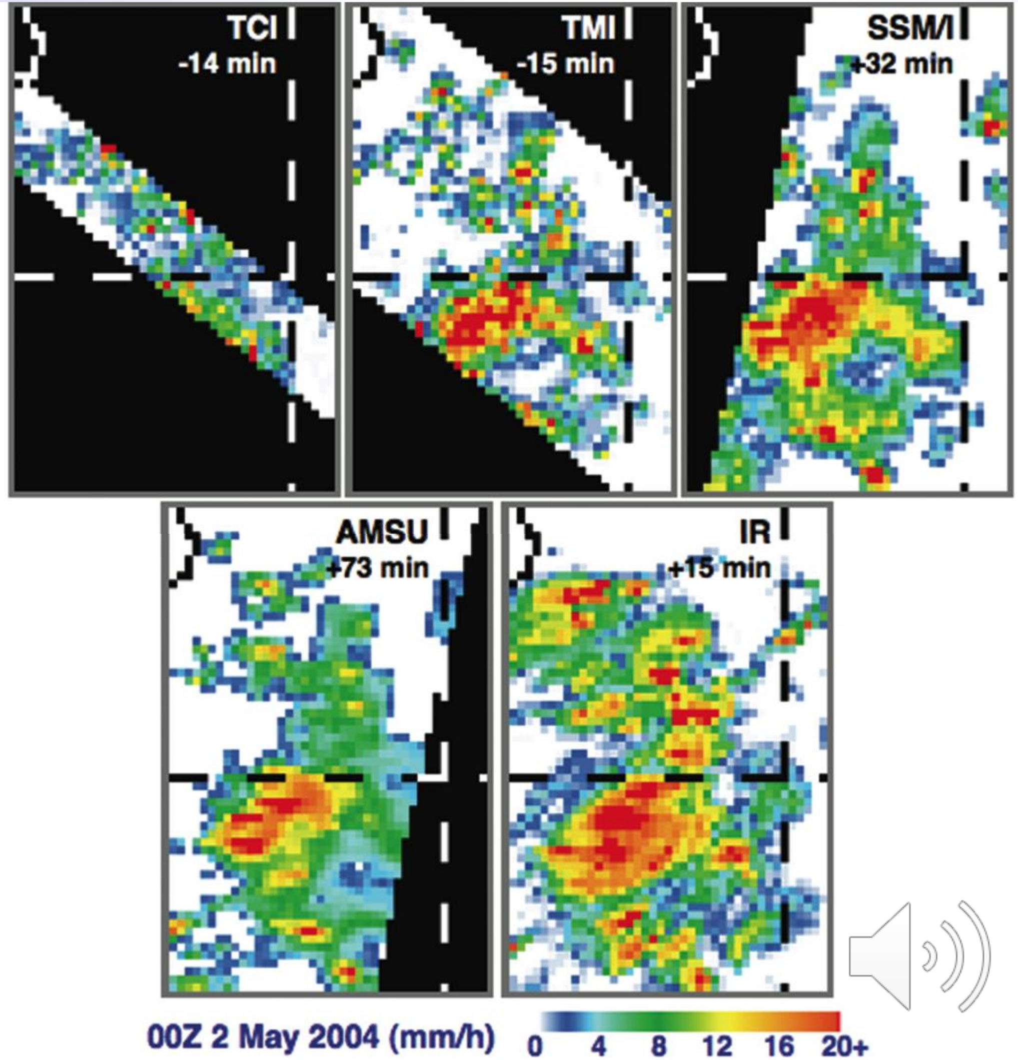
<u>Nearly coincident views</u> by 5 sensors southeast of Sri Lanka

The offset times from 00Z are below the "sensor" name

The estimates are related, but differ due to

- time of observation
- resolution
- sensor/algorithm limitations

Combination schemes try to work with all of these data to create a uniformly gridded product



3. IMERG – Quick description (1/2)

IMERG is a unified U.S. algorithm

- based on code from NASA, NOAA, and U.C. Irvine
- processed at PPS (GSFC)

IMERG is a single integrated code system

- multiple runs for different user requirements for latency and accuracy
  - "Early" – 4 hr (flash flooding)
  - "Late" – 14 hr (crop forecasting)
  - "Final" – 3 months (research)
- time intervals are half-hourly and monthly (Final only)
- 0.1º global CED grid
  - morphed precip 90º N-S, frozen surface masked out
  - IR covers 60º N-S

Datasets listed in *https://gpm.nasa.gov/data/directory*

- access to alternate formats at PPS, GES DISC
- documentation

	Half-hourly data file (Early, Late, Final)
1	*[multi-sat.] precipitationCal*
2	[multi-sat.] precipitationUncal
3	*[multi-sat. precip] randomError*
4	[PMW] HQprecipitation
5	[PMW] HQprecipSource [identifier]
6	[PMW] HQobservationTime
7	IRprecipitation
8	IRkalmanFilterWeight
9	*[phase] probabilityLiquidPrecipitation*
10	*precipitationQualityIndex*
	Monthly data file (Final)
1	*[sat.-gauge] precipitation*
2	*[sat.-gauge precip] randomError*
3	GaugeRelativeWeighting
4	*probabilityLiquidPrecipitation [phase]*
5	*precipitationQualityIndex*

3. IMERG – Quick description (2/2)

Overall calibration is provided by TRMM and GPM Combined Radar-Radiometer Algorithm (CORRA)

- TRMM June 2000-May 2014, GPM thereafter
- TRMM-era microwave calibrations over 33ºN-S and
- blend with adjusted monthly climatological GPM-era microwave calibrations over 25º-90º N and S

IMERG is adjusted to GPCP monthly climatology zonally to achieve a "reasonable" bias profile

- the GPM core product biases are similar (by design)
  - these profiles are systematically low in the extratropical oceans compared to
    - GPCP monthly Satellite-Gauge product is a community standard climate product
    - Behrangi Multi-satellite CloudSat, TRMM, GPM (MCTG) product
- over land this provides a first cut at the adjustment to gauges that the final calibration in IMERG enforces
- similar issue in the TRMM era

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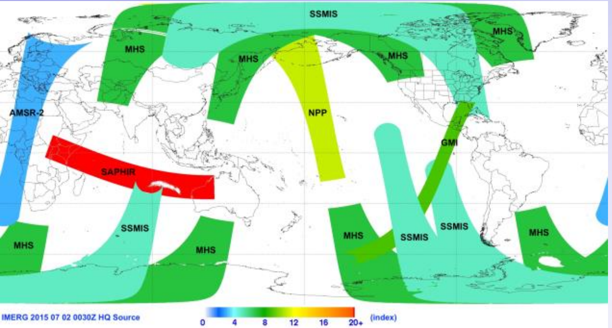
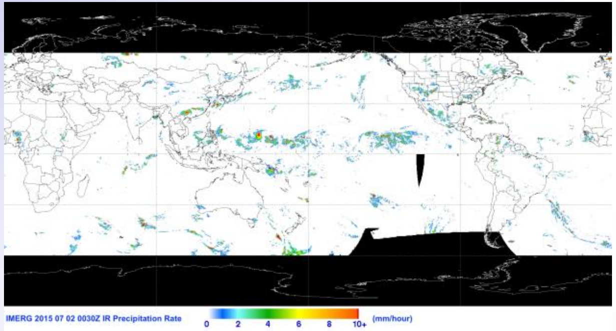
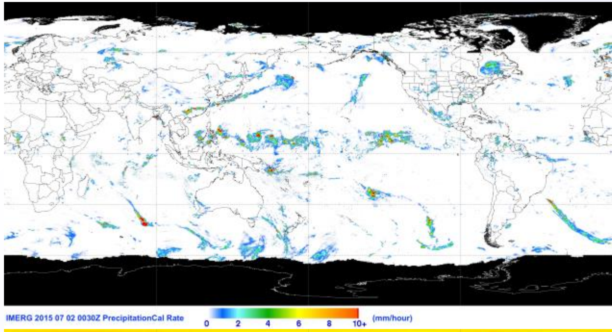
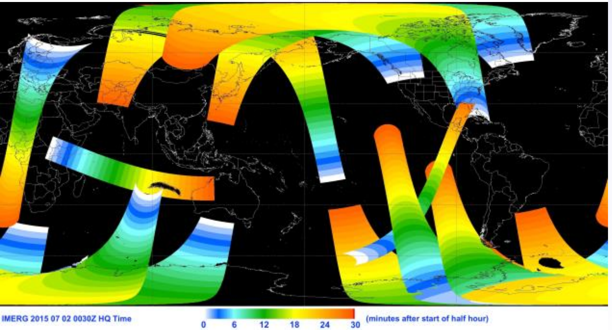
3. IMERG – Examples of Data Fields





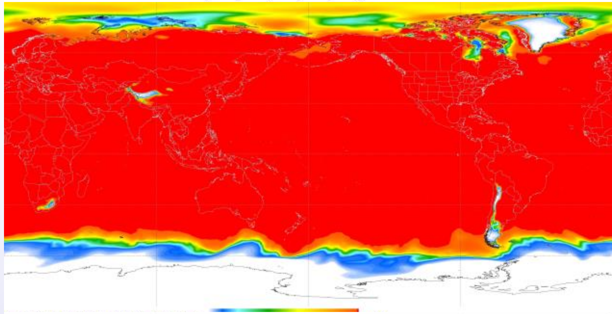


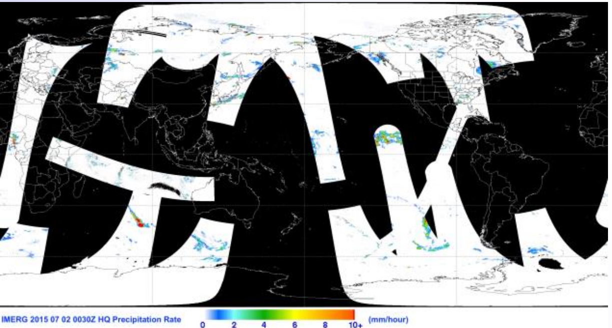


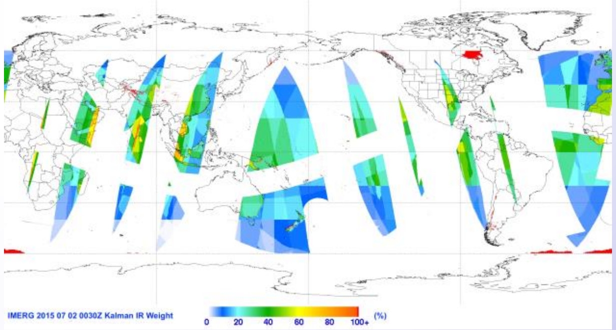
PMW sensor | IR precip | cal precip (uncal precip)

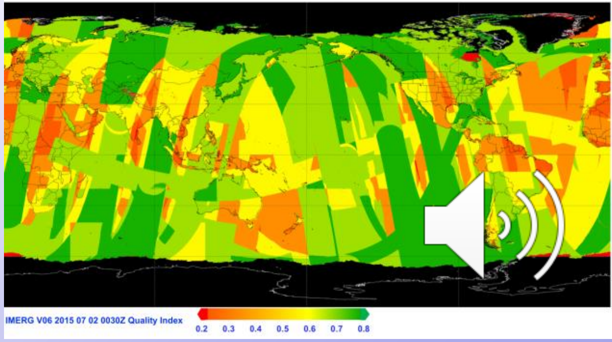
PMW time into half hour | **2 July 2015 0030 UTC** | probability of liquid phase

PMW precip | IR weight | Quality Index









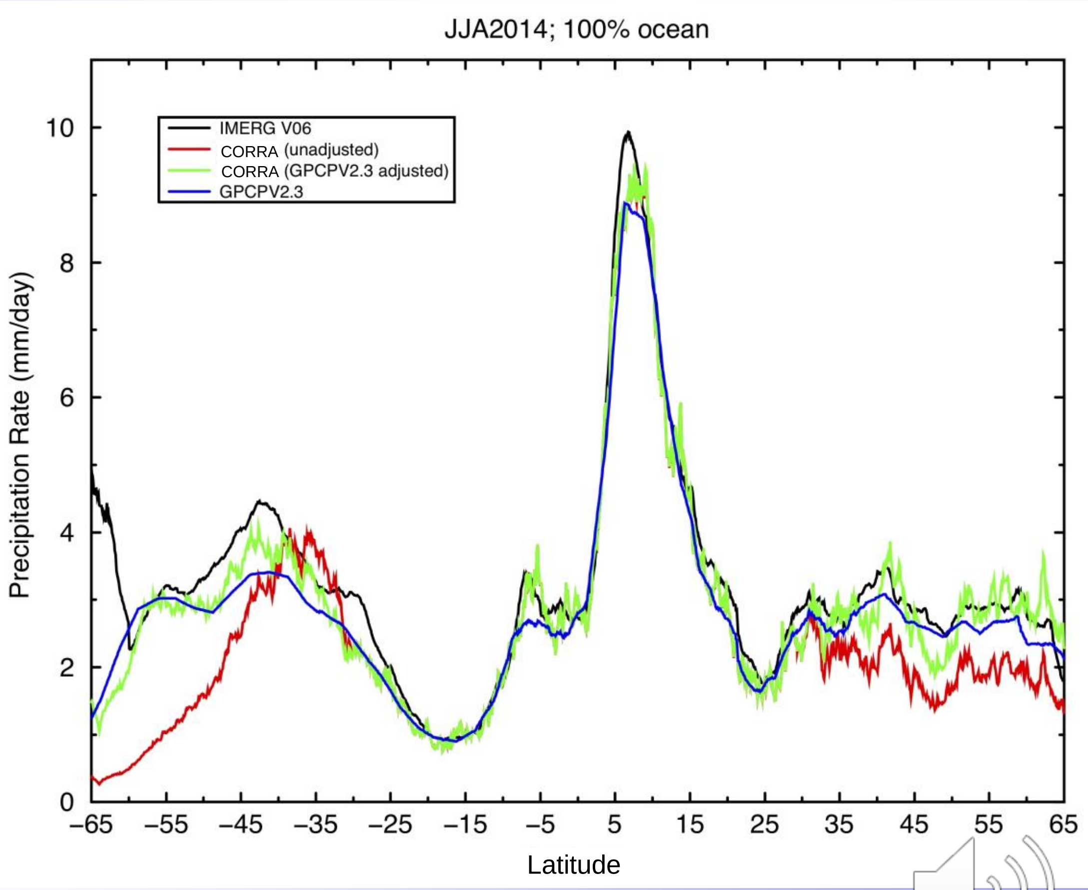
4. Results – Calibration

Calibration sequence is

- CORRA climatologically calibrated to GPCP over ocean outside 30ºN-S
- TMI/GMI calibrated to CORRA
- GPM constellation climatologically calibrated to TMI/GMI

Adjustments working roughly as intended

- CORRA is low at higher latitudes
- adjustments in Southern Ocean are large and need analysis
  - IMERG subsetted to coincidence with CORRA is much closer to CORRA



D. Bolvin (…AI; GSFC)

4. Results – Ocean (50ºN-S) Precip Timeseries

V06 Final Run starts June 2000

V06 is higher than 3B43 (TMPA) and GPCP over ocean

TRMM-era IMERG has a strong semi-annual signal

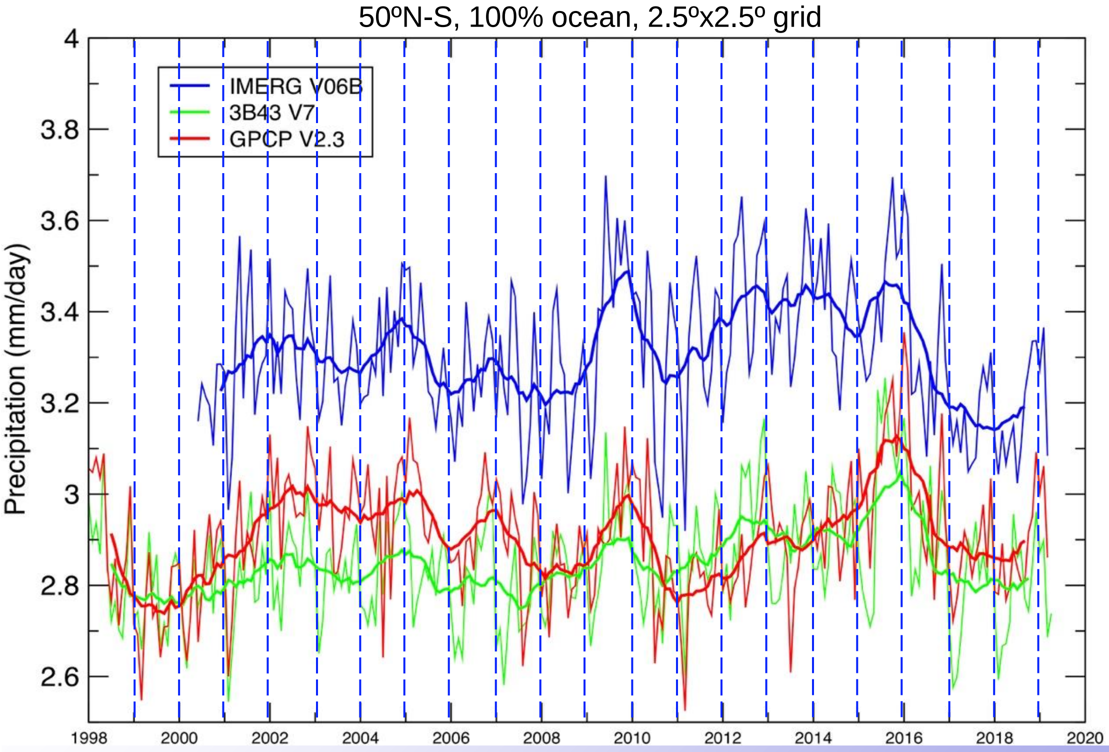
- GPM-era IMERG and 3B43 dominated by the annual cycle

Interannual variation

- has similar peaks/troughs for all datasets
- GPCP (passive microwave calibration) lags phase of 3B43 (through 2013), IMERG (both PMW/radar calibration)
- after September 2014, 3B43 (PMW calibration) matches GPCP phase

Additional multi-year variations

- IMERG and 3B43 are High Resolution Precipitation Products, not CDRs



E. Nelkin (SSAI; GSFC)

4. Results – Tropical Ocean (20ºN-S) Monthly Precip Histogram Timeseries

Histogram of Final Run <u>monthly</u> tropical oceanic precip on 0.1º grid, 20º N-S (top)

- log(counts) to help draw out small values

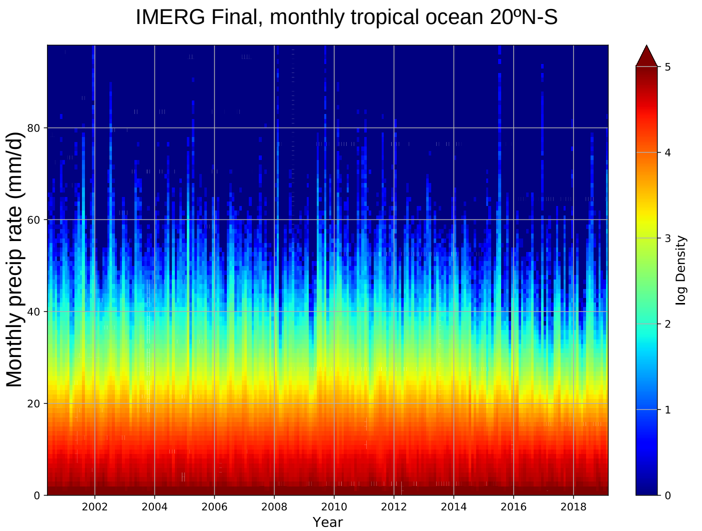
Anomaly helps guide interpretation (bottom)

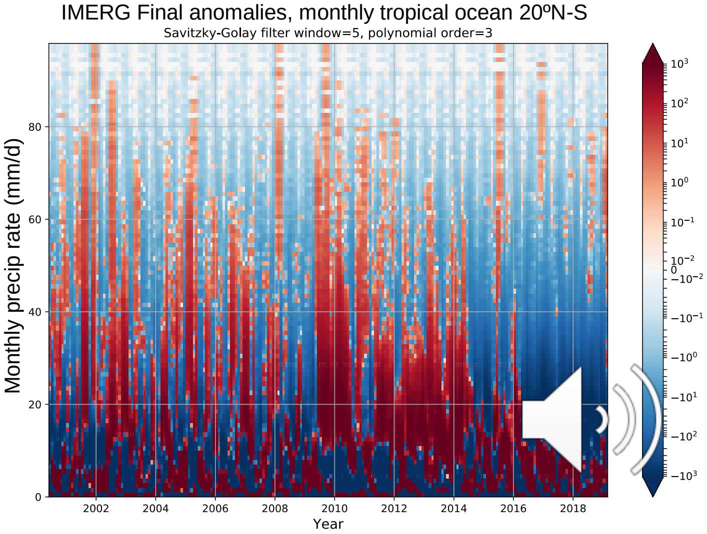
- log scale in both directions from zero
- filtered in time to emphasize main features

Initial impressions

- mid-to-high rates sometimes (2009-10) vary together, but not always (2006-07)
- lower rates tend to vary in the opposite direction
- start of GPM calibration (June 2014) seems to shift the PDF to lower rates
- persistent mid-range positive anomalies in 2009-14 remain to be explained

This discussion will help determine reliability for trend analysis





Potter et al. (2020)

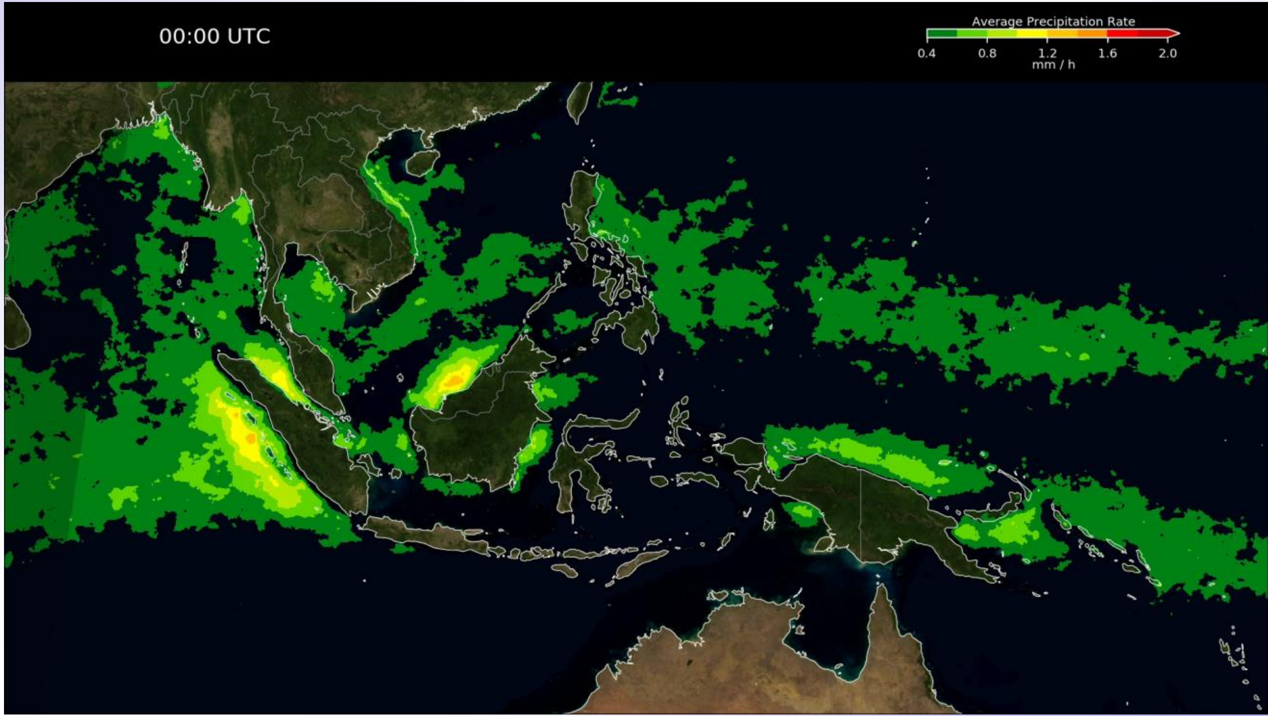
4. Results – Late Run, September-November Diurnal Cycle, Maritime Continent

Average September-November for 2001 to 2018, Late Run

- day/night shading
- Blue Marble land
- smoothed in space and time
  - even 18 years of seasonal data still has lumps

Reminiscent of TMPA, but

- more detailed, broader spatial coverage
- no interpolations between the 3-hourly times
- less IR-based precip used (which tends to have a phase lag)



J. Tan (USRA; GSFC)

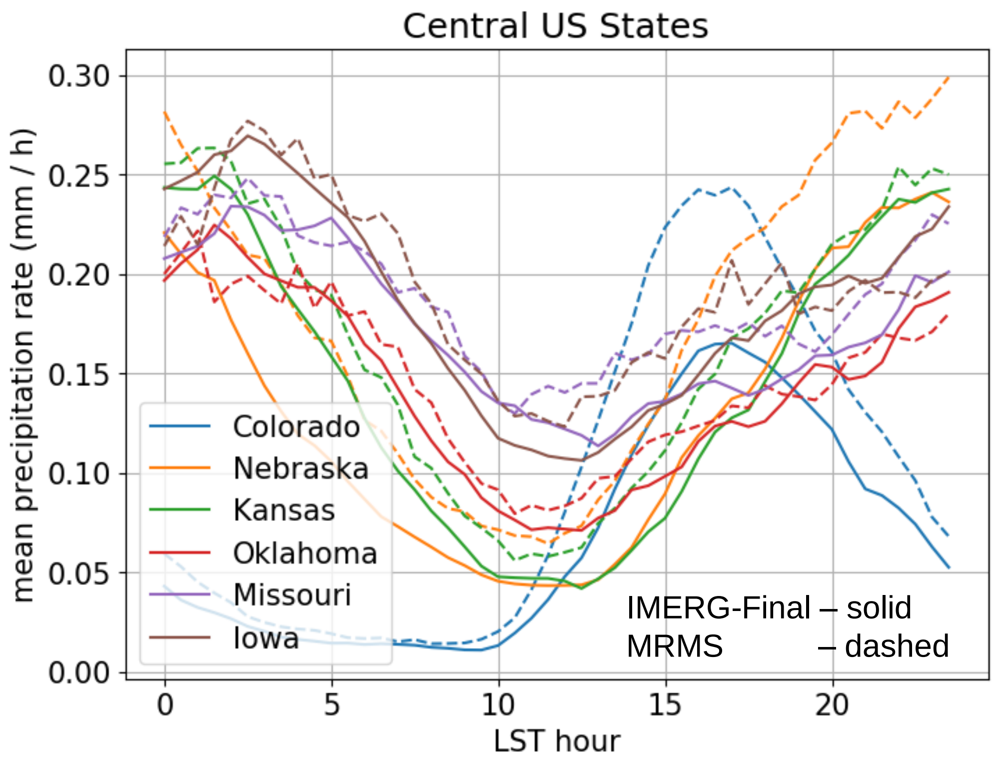
4. Results – Final Run, June-August Diurnal Cycle in Central U.S. (GPM Era)

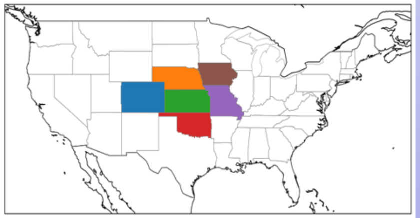
Average June-August for 2014 to 2018 (5 summers) for 6 states, Final Run

Compared to Multi-Radar Multi-Sensor (MRMS, dashed), Final (solid) shows:

- lower averages (despite use of gauge data)
- lower amplitude cycle in Colorado
- higher amplitude cycle in Iowa
- very similar curve shapes, peak times

This version of MRMS only starts in 2014, so an extended comparison requires different data



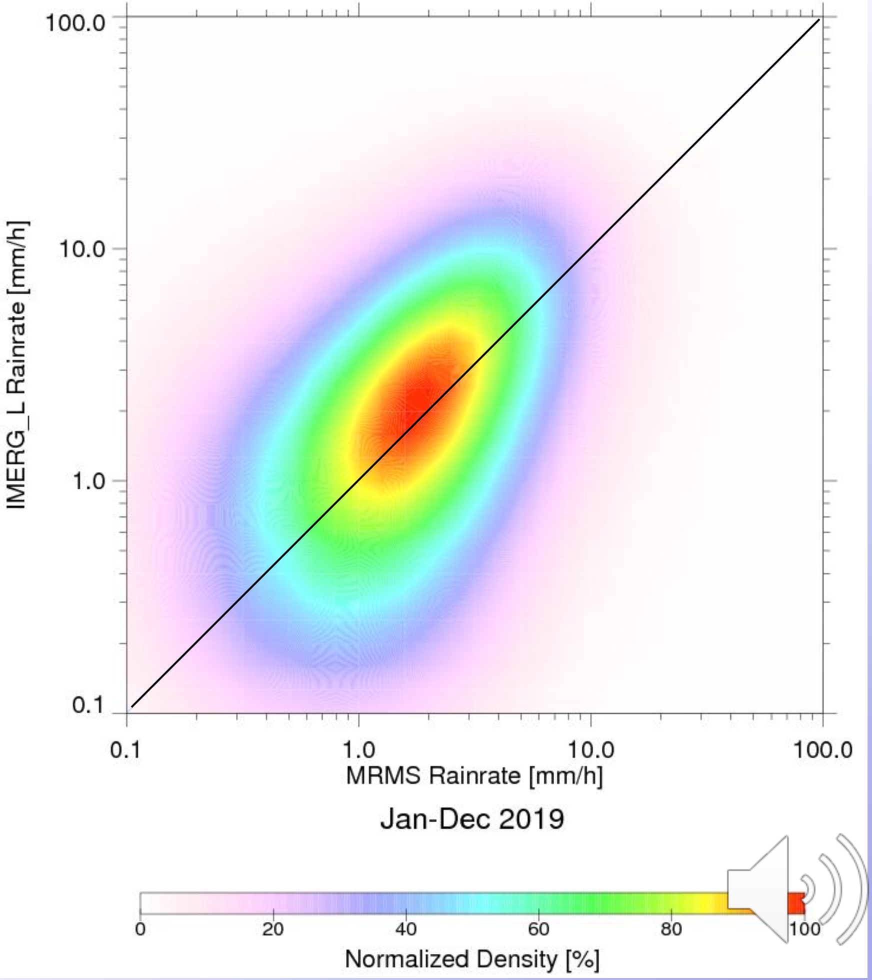


J. Tan (USRA; GSFC)

4. Results – IMERG Late Over CONUS

IMERG bias varies by location and weather regime, but in general

- comparison to MRMS over CONUS at half-hourly 0.1^o scale for January-December 2019
- low(high) at low(high) end
- mean positive bias
- this particularly affects applications that depend on extremes, like flooding
- tracking down the high bias has proved "challenging"

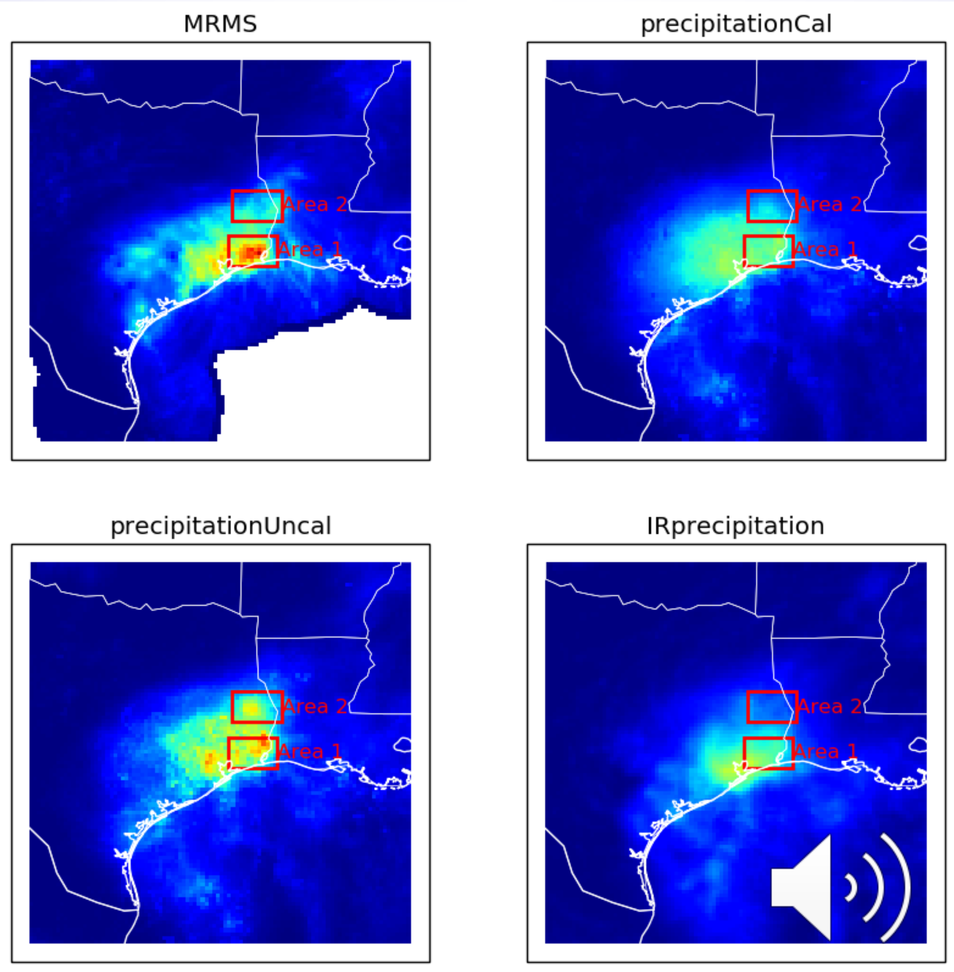


GPM GV Office

4. Results – Hurricane Harvey, 25-31 August 2017, IMERG Final and MRMS (1/2)

Harvey loitered over southeast Texas for a week

- MRMS considered the best estimate
  - some questions about the details of the gauge calibration of the radar estimate
  - over land
- Uncal (just the intercalibrated satellite estimates) under(over)-estimated in Area 1(2)
  - should be similar to Late Run
- Cal (with gauge adjustment) pulls both areas down
- microwave-adjusted PERSIANN-CCS IR has the focus too far southwest

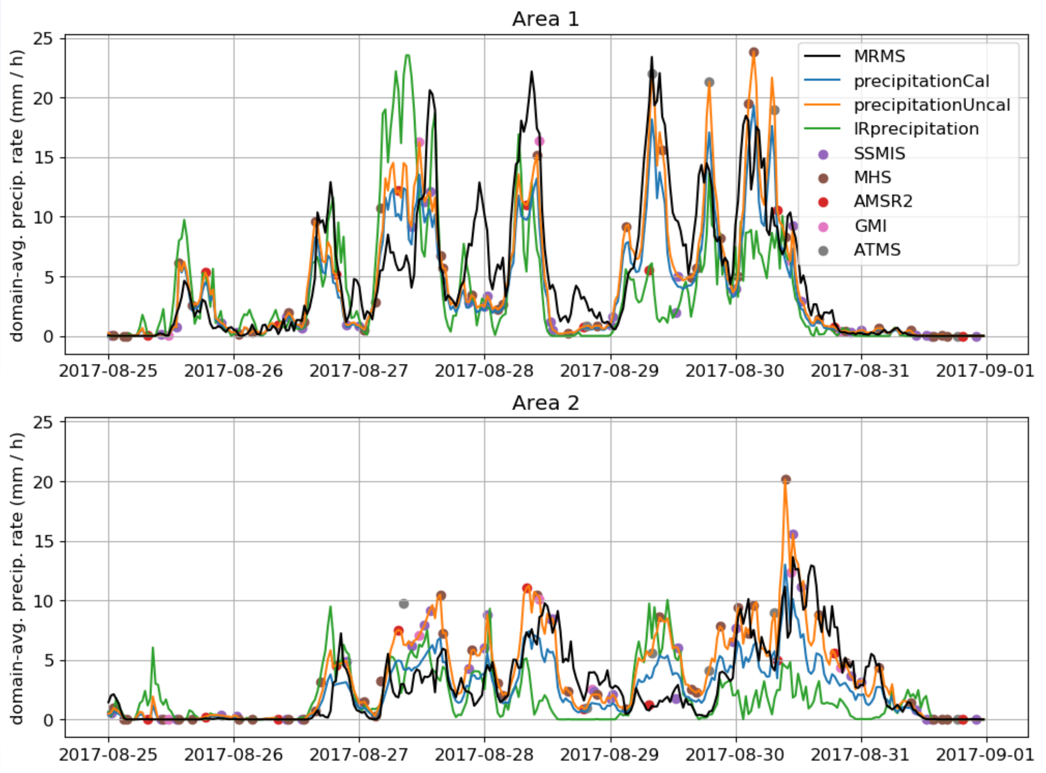


Huffman et al. (2020) and J. Tan (USRA; GSFC)

4. Results – Hurricane Harvey, 25-31 August 2017, IMERG and MRMS (2/2)

IMERG largely driven by microwave overpasses (dots)

- except duplicate times
- not just time interpolation
  - systems move into / out of the box between overpasses
- satellites show coherent differences from MRMS
  - PMW only “sees” the solid hydrometeors (scattering channels), since over land
  - IR looks at Tb within “clustered” data
  - both are calibrated to statistics of time/space cubes of data
    - Cal is basically *(Uncal x factor)*
  - short-interval differences show some cancellation over the whole event
    - but several-hour differences can be dramatic



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5. Looking Ahead to Version 07

Input data issues

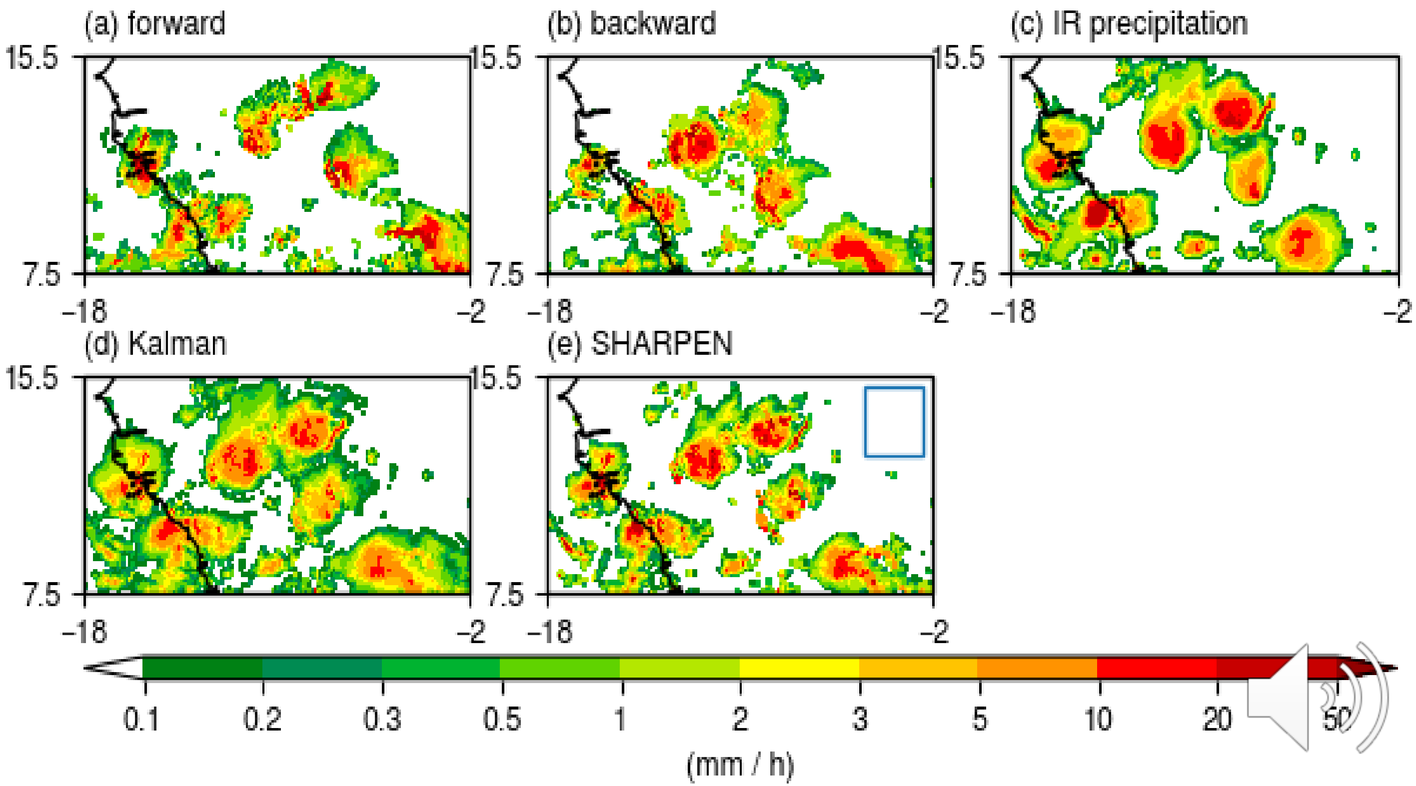
- quality control for GOES-W noise
- more-advanced IR algorithm: Precipitation Estimations from Remotely Sensed Information Using Artificial Neural Networks (PERSIANN) Dynamic Infrared–Rain rate model (PDIR)
- assess the degree to which GPROF MW estimates can be used over snow/ice surfaces
- early indications that estimates are useful over “warm” snow/ice surfaces
- gaps would still exist in coldest regions

Multi-satellite issues

- raise all caps on precipitation rate to 200 mm/hr
- add more inputs to compute morphing vectors
- variable name changes
  - HQprecipitation ➔ MWprecipitation
  - HQobservationTime ➔ MWobservationTime
  - HQprecipSource ➔ MWprecipSource
  - precipitationCal ➔ precipitation
  - IRkalmanFilterWeight ➔ IRinfluence
- SHARPEN = Scheme for Histogram Adjustment with Ranked Precipitation Estimates in the Neighborhood

5. Looking Ahead to Version 07 – SHARPEN

- undo distortion of PDF when averaging precipitation during morphing
- use local quantile mapping from morphed to input PDFs
- the datasets input to the Kalman filter have similar PDFs (top row)
- the Kalman-filtered result (d) has larger coverage, lower maximum rates because it's a weighted average
- the SHARPEN'ed precipitation PDF (e) is closer to the input precipitation PDFs



Example over West Africa for 00:00-00:30 UTC, 1 July 2018. The blue square in (e) shows the size of the "local" 25x25 template. [Tan et al. 2021]

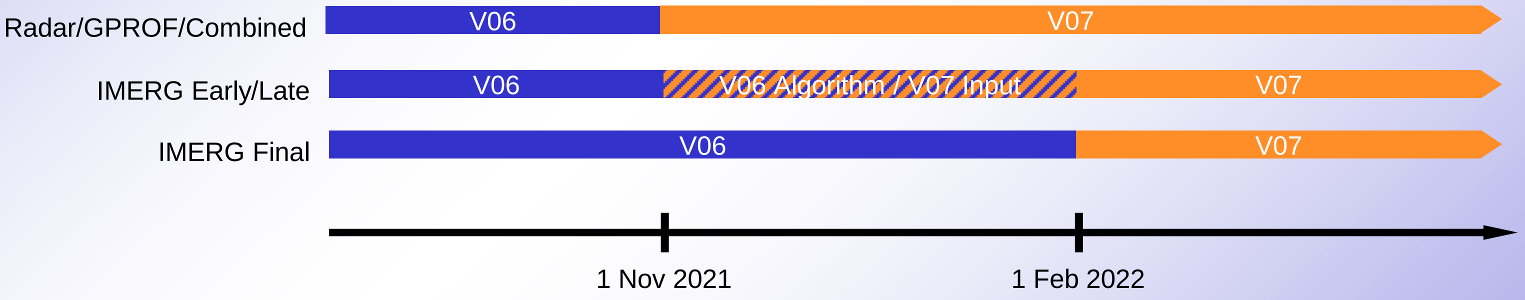
5. Looking Ahead to Version 07 – Schedule

TMPA ended with December 2019

- the products are still available, but users are encouraged to move to IMERG

The Version 07 release is happening later than originally planned

- 1 November: radar, GPROF, and Combined reprocessings start
- 1 February: IMERG reprocessing starts, but
- 1 November: IMERG Early and Late Runs must shift from V06 to V07 GPROF and Combined near-real-time inputs



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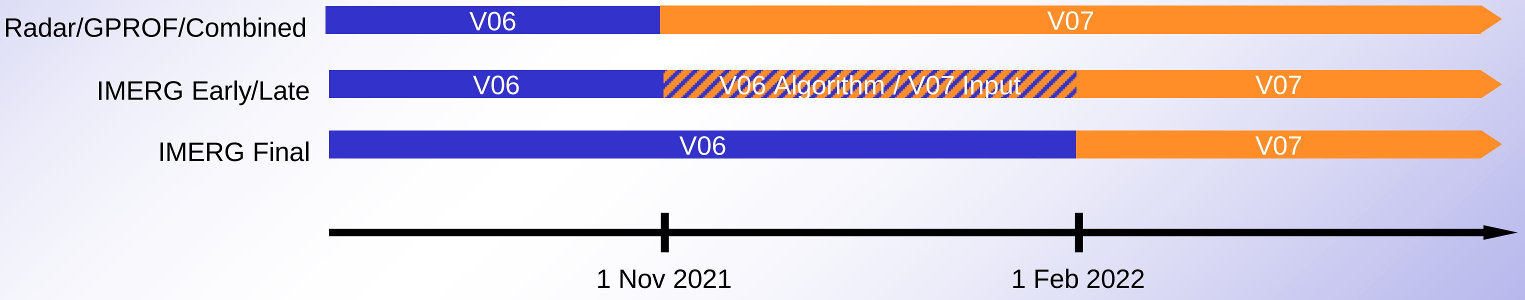

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